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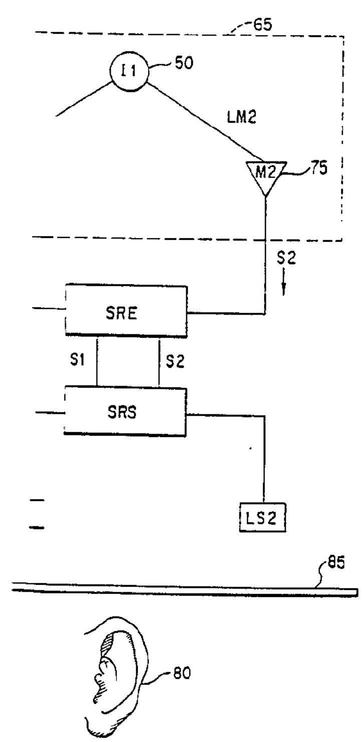
With amended claims.

(54) Title: MULTIDIMENSIONAL STEREOPHONIC SOUND REPRODUCTION SYSTEM

(57) Abstract

One-dimensional reproduction of stereophonic sound, wherein at least two microphones (70, 75) sense the sounds produced by at least one sound-generating point source (50), is achieved by reproducing the sounds sensed by the microphones (70, 75) through at least two transducers (LS1, LS2) spaced a distance apart, the reproduced sounds comprising sets of incident travelling sound waves, each set of incident travelling sound waves originating from a different transducer, transforming on a sympathetically vibratable sound-receiving surface (85) located between the transducers and the listener (80) the sets of incident travelling sound waves into corresponding sets of waves which travel toward one another along said surface and causing the different sets of waves travelling along said surface to interfere with one another to produce in a direction perpendicular to the surface separate and distinct standing waves, each standing wave representing an individual sound-generating point source being produced at locations along the surface relative to the transducers (70, 75) corresponding to the location of each sound-generating point source (50) relative to the microphones.



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MULTIDIMENSIONAL STEREOPHONIC SOUND REPRODUCTION SYSTEM

Field of the Invention

The present invention relates to the reproduction of multidimensional sound in front of a listener. More particularly, it relates to a novel system and method for the emulation of the relative spatial positioning of sound sources (e.g. musical instruments, voices) recorded or broadcast by conventional stereophonic equipment.

Background of the Invention

A person attending a "live" performance at an orchestral hall will hear many different sounds at the same time, for example, sounds originating from strings, wind or percussion instruments and voices. When listening to live music, the listener not only hears the individual sounds emanating from the musical instruments and/or singers, but also senses the specific locations where the instruments and/or singers are located. For example, the listener would hear the sounds generated by the french horns emanating from the right side of the stage where the french horn section is located, the sounds generated by the violins emanating from the center of the stage where the violins are located, and sounds generated by the tympani on the left where the percussion section is located. This aspect of determining the relative location of the

instruments will be referred to herein as three-dimensional sound.

The concept of stereophony was introduced in an attempt to emulate in a listening room with a prerecorded or broadcast sound source the three-dimensional sound that would have been heard during a live performance of the same program.

In stereophony, a sound is typically recorded stereophonically by recording on separate, individual channels the sounds received by each of a plurality of microphones located at predetermined positions in the recording studio or concert hall. The sounds can be recorded on media such as a record, tape or compact disc. The recorded sound can subsequently be reproduced on a stereophonic or two-channel reproduction system such as a home stereo system. A home stereo system typically comprises a means for reading the sound information in the individual channels stored on the media, and generating electronic signals representative of the information. The electronic signals are amplified and fed to electronic-to acoustic transducers, such as loud-speakers, to generate the sound waves which the listener then hears.

It is desirable that the recorded sound reproduced on a stereo system sound the same as the original sound. In an attempt to achieve the best possible sound quality, stereo speakers are typically positioned a distance apart from one another. This is illustrated in Fig. 1. Instruments I1, I2 and I3 which, in this example produce music, are positioned at locations 10, 12 and 14 in a recording studio 16. Also situated in the recording studio 16 are two microphones M1 and M2 positioned at

locations 18 and 20. The microphones M1 and M2 provide the means to record the sounds received at locations 18 and 20. Electrical impulses representative of the sounds received through the microphones M1 and M2 are recorded on separate channels by sound recording and reproduction unit 22. In listening room 24, the sound recording and reproduction unit 22 is connected to speakers S1 and S2 at locations 26 and 28. Speakers S1 and S2 are positioned apart from one another in simulation of the separation of microphones M1 and M2. Speaker S1 reproduces the sounds recorded from microphone M1 and speaker S2 reproduces the sounds recorded from microphone M2. Thus, theoretically, the listener, positioned at location 30, would expect to hear the reproduced music with the same sensation if he were in the recording studio because of the separation of speakers S1 and S2. In reality, however, the listener instead hears instruments I1, I2, and I3 originating simultaneously from both speakers. This produces an artificial, distorted sound because each of the original sounds, emanating from instruments I1, I2 and I3, originates from an individual distinct location, 10, 12 and 14, respectively, dictated by the positions of the instruments, not from two separate locations as the listener perceives through the conventional stereophonic sound reproduction system. More specifically, the listener in the listening room hears a mixture of two distinct sources of sound from two speakers representative of the combination of microphones/speakers M1/S1 and M2/S2 which transmit the combination of sounds originating from point sources I1, I2 and I3.

Some improvement in the reduction of such distortion of reproduced sound can be achieved through the

use of stereo headphones. Since the sounds out of the right and left speakers are fed directly and exclusively into the respective right and left ears of the listener, the mixing of sounds from the right and left speakers is substantially eliminated. However, the real situation is not completely emulated and the listener cannot discern the relative position accuracy of the individual sound sources.

For the accurate reproduction of sound, the listener should be able to hear three distinct sources of sound, (i.e., the instruments) as well as the locations of the sound sources relative to one another (since that is what the listener would hear if he were listening to a "live" performance, that is, if the listener were physically located in front of sound producing instruments I1, I2 and I3).

Accordingly, it is an object of the present invention to provide a system of stereophonic sound reproduction which permits a greater degree of freedom from distortion in the perceived relative locations of the individual instruments than was heretofore possible in conventional listening rooms.

Another object is to provide an apparatus for achieving according to the system of the invention the stereophonic reproduction of prerecorded sound having a greater degree of freedom from distortion in the perceived relative locations of the individual sound sources than was heretofore possible in conventional listening rooms.

Yet another object of the invention is to provide a method of stereophonic sound reproduction in the listening room which is comparatively free of distortion in

the listener-perceived location of the individual sound sources.

These and other objects of the invention as well as the advantages thereof can be had by reference to the following detailed description and claims.

Summary of the Invention

The foregoing objects are achieved according to the present invention by means of a system which provides a means for reproducing stereophonic prerecorded sound which greatly improves the quality of the reproduced sound which the listener hears. The sounds reproduced through the system of the present invention closely emulate the sounds as originally generated by the sound sources, particularly with regard tp the locations of the sound sources relative to one another.

Through the method and apparatus of the present invention, the sounds emanating from the sound transducers, which comprise sound waves travelling through air, are transformed on the sound-receiving surface of a sympathetically vibratable material or "sound screen" into waves of the material which travel along the surface towards one another. These waves combine and interfere with one another thereby producing in effect an acoustic-to-acqustic transducer in the form of standing waves on the material, each standing wave corresponding to and representing a given sound source. The location of each of the standing waves produced occurs at the same relative position as the position of the corresponding original sound source. The standing wave, like the diaphram of a speaker cone, produces sounds which emulate the individual

sound sources. Not only does the listener distinctly hear the original sound sources, but the listener can also perceive and determine the relative positions of the original sound sources as the listener would be able to do if he were listening to "live" music.

Brief Description of the Drawings

The features and advantages of the invention will be more readily apparent from the following drawings wherein:

Fig. 1 illustrates schematically the physical layout of a recording studio and listening room, as discussed hereinabove.

Fig. 2 illustrates schematically an embodiment of the system of the present invention.

Fig. 3 illustrates another schematic embodiment of the system of the present invention.

Fig. 4 illustrates the formation of a standing wave from interfering surface waves on the sound screen.

Fig. 5 illustrates another embodiment of the system of the present invention.

Fig. 6 illustrates a self-contained embodiment of the system of the present invention.

Description of Preferred Embodiments

Through the system of the present invention, the quality of reproduced stereophonic media is improved to an extent such that the reproduction is sensed and perceived by the listener as being "live" rather than prerecorded. Not only does the system of the present invention emulate each original individual sound source, but it also emulates

said sources at the same relative locations as the original sound sources. Thus, if the original sound sources are a violin situated on the left, a drum situated on the right, and a piano situated between the drum and violin, the listener will perceive three distinct sources of sounds, a violin, drum and piano, the violin emanating from the left, the drum emanating from the right and the piano emanating from a location between the violin and drum.

The present invention is illustrated schematically in Fig. 2. In this illustration, the original sound source, a single musical instrument I1, is located at position 50 in recording studio 65. Microphones M1 and M2 are located in the recording studio 65 at locations 70 and 75, and at distances LM1 and LM2 from the sound source I1, respectively. The microphones M1 and M2detect the sounds or sound waves as they exist at the locations 70 and 75, respectively and convert the sound waves into electronic signals S1 and S2. The electronic signals S1 and S2 can be recorded using stereophonic recording equipment SRE and reproduced for listening from transducers in the form of loud speakers LS1 and LS2 through a stereophonic reproduction system SRS such as are found in the home.

The sound waves sensed at microphones M1 and M2 originate from a single sound source I1 at a single position 50. Without using the method and apparatus of the present invention, a listener located at 80 will concurrently hear multiple sounds from two sound sources, transducers LS1 and LS2, even though the original sound source was only a single instrument I1. Therefore, instead of hearing a single sound source the listener hears two

sound sources which mix with one another to produce artificial, distorted sound.

In the method of the present invention, the sound waves originating from speakers LS1 and LS2 are caused to interfere with one another on the sound-receiving surface of a sympathetically vibratable material or "sound screen" 85 prior to reaching the listener at 80. In this way, the incident travelling sound waves from the speakers LS1 and LS2 are caused to constructively interfere with one another on the sound screen 85, thereby generating standing waves on the material of the sound screen. The standing waves drive, in effect, a speaker cone (i.e., the material of the sound screen) which produces an enhanced sound emulating the sound of the original sound source.

Generally, the size of a musical instrument is small compared to the wavelength of the sounds in the air generated by it, and therefore can be considered, in the present context, as equivalent to a point sound source. Similarly, microphones M1 and M2 and speakers LS1 and LS2 may each be considered equivalent to point sources. Thus, the effect of wave interference which occurs with the incident travelling sound waves from the speakers LS1 and LS2 can be analogized to the interference effect of light waves illustrated by Young's experiment. This famous experiment, described in most physics textbooks, confirms the wave nature of light. In the experiment, a point source of light illuminates two parallel slits spaced a small distance apart. The two slits function as two coherent-like light sources because the light originates from the same light point source. The resultant light emitted from the two slits is projected onto a screen

placed behind the slits and shows a light wave interference pattern. If the light point source is moved, then the interference pattern moves synchronously and in the opposite direction.

The interference effect illustrated by Young's experiment can be applied to sound waves. As discussed earlier, the original sound source I1, microphones M1 and M2, and speakers LS1 and LS2 are considered point sources and therefore the sound waves emitted from the speakers exhibit coherent-like wave properties. The stereophonic recording and reproduction unit will maintain the acoustic phase and amplitude relationships of the original sounds. However, in conventional systems, the distance from the coherent-like speakers (equivalent to waves emanating from the point sources) at which the effects of interference are manifested in the human ear depends on several variables, including the frequency, location, and time occurrence of the sound source. This creates very complex interference patterns which gives rise to distortion in the sound heard by the listener. Because music comprises sounds covering a broad range of frequencies, there is no one distance from the speakers at which the listener may hear the different constructive interference effects by location and time of occurrence with respect to all the sounds which comprise the music.

Thus, by causing the incident travelling sound waves emitted from the transducers or speakers LS1 and LS2 to interfere with one another on the sound screen before they reach the listener, resultant standing waves are produced on the sound screen which correspond to the original sound source, and drive an acoustic-to-acoustic

transducer from which the quality of sound emitted closely emulates that of the original sound source. In addition, the one dimensional azimuthal position of the original sound source is maintained.

A preferred embodiment of the invention is illustrated in Fig. 3. Stereophonic sound reproduction equipment 100 such as a record player, tape player or a compact disc player outputs from a left 105 and right 110 channel. The electronic signals are amplified in amplification means 111 and 112 and used to drive electronic-acoustic transducers 115 and 116 located in listening room 117. The transducers 115 and 116 convert the electronic signals to sounds.

To accomplish the objects of the invention, the effective speaker diameter should be small such that the acoustic impedance of moving coil waves matches that of a large acoustic resonator 118 which comprises a cabinet, 119, sound screen 120 and two left and right speakers 115 and 116 at locations 121 and 125. Conventional speakers which have large cone diameters are less desirable for use in the system of the present invention even at low frequency ranges, because the sound screen 120 and the enclosure cabinet 119 form a very wide frequency range resonator. The matching of two speaker characteristics is not critical as has been the case in conventional stereo systems. The sound output from sound screen 120 is uniform over the entire surface thereof due to the fact that standing waves on the sound screen possess compositive sound characteristics of the two speakers 115 and 116, the sound screen 120 and enclosure cabinet 119. If one were to calculate the low frequency limit of this invention roughly

from the dimension ratio between a conventional speaker cone diameter and the horizontal dimension of sound screen 120 one could obtain the following number: conventional woofer speaker diameter 12 inches (freq. limit around 30 Hz) and typical horizontal dimension of a sound screen is approximately 10 feet.

Low frequency limit of sound screen f_{low}

$$f_{low} = 30 \times \frac{12}{120} = 3\text{Hz}$$

In this invention, the low frequency response limit is no longer dependent on the physical characteristics of the transducers 115 and 116.

With regard to high frequency response limit, the improvement in tonality in the high audio frequency range is significant because the non-linear characteristics of sound screen vibrations known from fundamental mechanical theory provide even higher harmonic wave generations of fundamental instrument and voice sound. The transducers 115 and 116 are preferably small in diameter compared to the wavelength of the sounds in air so as to function as equivalents of a point source whereby the effect of the subsequently generated standing wave is at a maximum, but a speaker cone such as conventional stereophonic equipment can be used. To drive the sound screen 120, stiff cones are preferred to balance out with the impedance of the sound screen. However, the diameter of the transducers should be sufficient to provide the proper response at low frequencies.

The transducers 115 and 116 are positioned at locations 121 and 125 which preferably correspond to the relative positions of the microphones through which the

original sounds were initially recorded. The emulation of "concert hall ambience" is achieved by the system of the present invention notwithstanding the fact that the separation of the transducers may differ from the separation of the microphones. Indeed, in actual practice, the separation of the transducers is substantially less than that of the microphones. The listener is positioned a distance "D" away at location 130. Sound screen 120 is placed between the transducers 115 and 116 and the listener at 130. The screen 120, at location 135 must be of a size and shape and be located such that the listener hears the enhanced sounds which emanate from the screen. Desirably, the width of sound screen 120 is at least as great as the separation between the transducers, and the separation of the sound screen from the transducers is less than the separation between the transducers.

The screen 120 can be of any rectilinear shape; however it is preferred that the screen be constructed in a rectangular or oblong shape. The screen can optionally be constructed in a non-planar elliptical or ellipsoidal shape surrounding the transducers thereby optimizing the acoustic interaction between the sound waves generated by transducers 115 and 116.

Thus, the screen 120 must be located at 135 in the path of the sound waves emanating from the transducers 115 and 116 so as to intercept the sound waves before they reach the listener to insure that only the sound waves emanating from the sound screen 120 are heard by the listener.

The sound screen 120 may consist of many types of compositions or combinations thereof. For example, the

screen may be constructed of stiff fabric or a combination of fabric and aluminum foil.

The characteristics of the material which form the sound screen dictate the range of frequency responses and therefore often the type of music which the screen is best suited for. A number of parameters contribute to the acoustical response of the material, including the flexibility of the material. For example, a cloth which is tightly stretched over a frame will have a higher frequency response than the same cloth placed loosely on the same frame. The applicant has found that a variety of materials from cloth to metal to ceramics may be used to achieve different responses. For example, materials such as cotton, linen, fiberglass and other artificial fibers can be used. It has been found that the thinner the cloth, the higher the frequency response. This also relates to the diameter of the thread, the tightness of the weave as well as the overall physical characteristics of the material itself. Foils made out of aluminum or other metals or alloys as well as silver and tungsten perform well in the high frequency range. In addition, crystal and ceramic films can be used, for example, diamond, alumina, zirconia, zirconia-titanium as well as graphite. The acoustic response of the materials can be modified somewhat by placing a coating on top of the material. Suitable coatings include varnish, lacquer, paint and epoxy as well as enamel.

Although the screen can be homogeneous, the sound screen may be sectioned into separate areas whereby different areas are more responsive to different frequency ranges. For example, the upper portion of the screen may

be aluminum foil with an extremely high frequency response to best react with the high frequency sounds. The middle portion of the screen can comprise a paint coated fabric which does well in the mid-range of frequencies and the lower portion of the screen may consist of a loosely woven material which is best responsive to the low frequency sounds.

The sound screen 120 provides a medium which intercepts the sound waves emitted from transducers 115 and 116 and permits the constructive interference of the sounds generated by the individual sound sources (i.e., instruments) which results in the output of enhanced stereophonic sound. The enhanced sounds not only sound better, but the relative positions of the original sound sources with respect to the microphones is emulated for each sound source. For example, if the sounds reproduced originated from a five piece band, five different sound sources would emanate from the sound screen, each one originating from a different piece of the band.

More particularly, referring to Fig. 4, the incident travelling waves 150 and 153 from transducers or speakers S1 at 155 and S2 at 160 are converted to surface stress or shear waves 165 and 170 when the incident travelling waves 150 and 153 impact the screen.

The incident travelling waves 150 and 153 originating from transducers S1 at 155 and S2 at 160 impact the screen at the same time and have the same frequency and phase characteristics since both waves originate from the same single sound point source (referring to Young's experiment). The surface waves 165 and 170 maintain the

same frequency and phase characteristics as the incident sound waves.

The shear waves 165 and 170 generated by the incident travelling waves 150 and 153 from the two speakers S1 and S2 will also have the same waves formed 165 and 170 which are transmitted to the opposite side of the screen and eventually collide and interfere with one another at 175, thereby emulating a single sound point source. The location of the collision corresponds to the position of the original single sound source with respect to the microphones. This interference causes the screen to vibrate at the frequencies of the original sound source thereby producing point source sounds which closely emulate the original sound point source at relative locations which correspond to the relative locations of the original sound sources.

Another embodiment of the present invention is designated in Fig. 5. In this embodiment, acoustic transducers S1 at 200 and S2 at 205 are positioned to face in a direction opposite to the listener "L" at 210. However the transducers 200 and 205 are positioned such that the acoustic outputs of the transducers travel in a direction towards an obstruction such as a wall 215 which comprises a rigid or solid (dense) material such as concrete. The sound screen 220 is placed between the wall 215 and the transducers 200 and 205 such that the sound screen 220 intercepts the sound waves from transducers S1 and S2 prior to reaching the wall 215. An air gap 222 is provideed between the sound screen 220 and the wall 215. The resulting enhanced sound waves comprising individual sound point sources emanate from the sound screen 220 in a

direction toward the wall 215. Those sound waves are then reflected off the wall toward the listener depending upon the combined local acoustic impedences of the screen 220 and wall 215. This reflector arrangement is preferably used for a large audience.

A speaker box-like arrangement is illustrated in Fig. 6. In this embodiment, two acoustic transducers 180 and 181 such as small area diaphragm speaker cones are placed in close proximity to one another in an enclosed casing such as a wooden cabinet or box 175. The direction of the speaker cones is towards the front of the box where the sound screen 190 is placed. This results in the enhanced sounds using a small self-contained unit. The size of the unit can be modified according to the size of the speakers.

CLAIMS

I claim:

1. A method for the one-dimensional reproduction of stereophonic sound wherein at least two microphones sense the sounds produced by at least one sound-generating point source, comprising:

reproducing the sounds sensed by the microphones through at least two transducers spaced a distance apart, said reproduced sounds comprising sets of incident travelling sound waves, each set of incident travelling sound waves originating from a different transducer;

transforming on a sympathetically vibratable sound-receiving surface located between the transducers and the listener the sets of incident travelling sound waves into corresponding sets of waves which travel toward one another along said surface; and

causing the different sets of waves travelling along said surface to interfere with one another to produce in a direction perpendicular to the surface separate and distinct standing waves, each standing wave representing an individual sound-generating point source being produced at locations along the surface relative to the transducers corresponding to the location of each sound-generating point source relative to the microphones.

2. A method according to claim 1 wherein the sound receiving surface is a material having a thickness which is small relative to its linear surface dimensions

and which is maintained at a tension such that the sets of incident travelling sound waves are transformed into corresponding sets of interfering surface waves that produce said separate and distinct standing waves.

3. A method according to claim 2 wherein the sound receiving surface is disposed in a plane parallel to an imaginary straight line connecting the transducers.

4. A stereo sound reproduction system which reproduces the sounds generated by at least one sound source and sensed by at least two microphones, said reproduction system reproducing for a listener distinct point sources of sounds each point source representing a different sound source at relative locations which emulate the locations of the sound sources at time of sensing, comprising:

at least two sound transducers spaced a distance apart to reproduce the sounds sensed by the microphones, said sounds reproduced by each sound transducer being a set of incident travelling waves;

a sympathetically vibratable sound-receiving surface comprising a sound screen located between the sound transducers and the listener, said sound screen comprising a material that intercepts each set of incident travelling waves produced by the individual sound transducers, and causes the generation of corresponding sets of surface waves which travel along the screen towards one another, said material permitting the interference of the surface waves to generate at least one standing wave, the number of distinct standing waves being approximately equal to the

number of sound sources, each standing wave corresponding to one of the sound sources at a location which emulates the relative location of the particular sound source at the time the sound was sensed by the microphones.

5. A stereo sound reproduction system according to claim 3 wherein the sound screen is disposed in a plane parallel to an imaginary straight line between the transducers.

6. A stereo sound reproduction system according to claim 5 wherein the width of the sound screen is at least as great as the separation between the transducers, and the separation of the sound screen from the transducers is less than the separation between the transducers.

AMENDED CLAIMS
[received by the International Bureau
on 18 September 1989 (18.09.89);
original claims 1 and 4 amended; other claims unchanged (2 pages)]

1. A method for the multidimensional reproduction of stereophonic sound wherein at least two microphones sense the sounds produced by at least one sound-generating point or coherent source, comprising:

reproducing the sounds sensed by the microphones through at least two transducers spaced a distance apart, said reproduced sounds comprising sets of incident travelling sound waves, each set of incident travelling sound waves originating from a different transducer;

transforming on a sympathetically vibratable sound-receiving surface located between the transducers and the listener the sets of incident travelling sound waves into corresponding sets of waves which travel toward one another along said surface; and

causing the different sets of waves travelling along said surface to interfere with one another to produce in a direction perpendicular to the surface separate and distinct standing waves representing the individual sound-generating point sources being holographically produced at locations along the surface relative, to the transducers corresponding to the locations of the sound-generating point sources relative to the microphones.

2. A method according to claim 1 wherein the 30 sound receiving surface is a material having a thickness which is small relative to its linear surface dimensions and which is maintained at a tension such that the sets of incident travelling sound waves are transformed into corresponding sets of interfering surface waves that produce said separate and distinct standing waves.

3. A method according to claim 2 wherein the sound receiving surface is disposed in a plane parallel to an imaginary straight line connecting the transducers.

4. A stereo sound reproduction system which reproduces the sounds generated by at least one sound source

and sensed by at least two microphones, said reproduction system reproducing for a listener distinct point or coherent sources of sounds which are phase conjugated, each point or coherent source representing a different sound source at relative locations which emulate the locations of the sound sources at time of sensing, comprising:

at least two sound transducers spaced a distance apart to reproduce the sounds sensed by the microphones, said sounds reproduced by each sound transducer being a set of incident travelling waves;

a sympathetically vibratable sound-receiving surface comprising a sound screen located between the sound transducers and the listener, said sound screen comprising a material that intercepts each set of incident travelling waves produced by the individual sound transducers, and causes the generation of corresponding sets of surface waves which travel along the screen towards one another, said material permitting the interference of the surface waves to generate at least one standing wave, the number of distinct standing waves being approximately equal to the number of sound sources, each standing wave corresponding to one of the sound sources at locations which emulate the relative location of the particular sound sources at the time the sound was sensed by the microphones.

5. A stereo sound reproduction system according to claim 3 wherein the sound screen is disposed in a plane parallel to an imaginary straight line between the transducers.

6. A stereo sound reproduction system according to claim 5 wherein the width of the sound screen is at least as great as the separation between the transducers, and the separation of the sound screen from the transducers is less than the separation between the transducers.

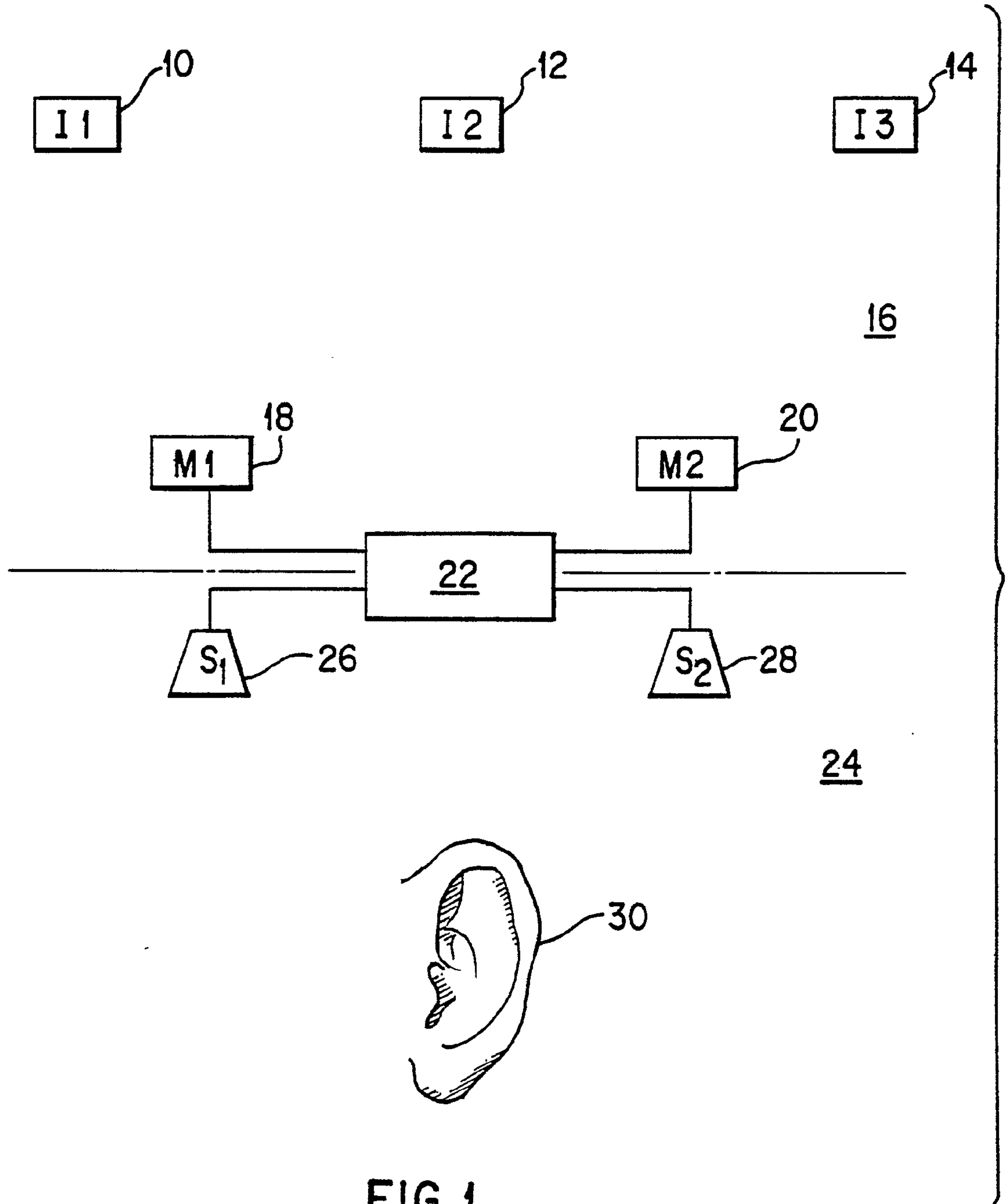

FIG. 1

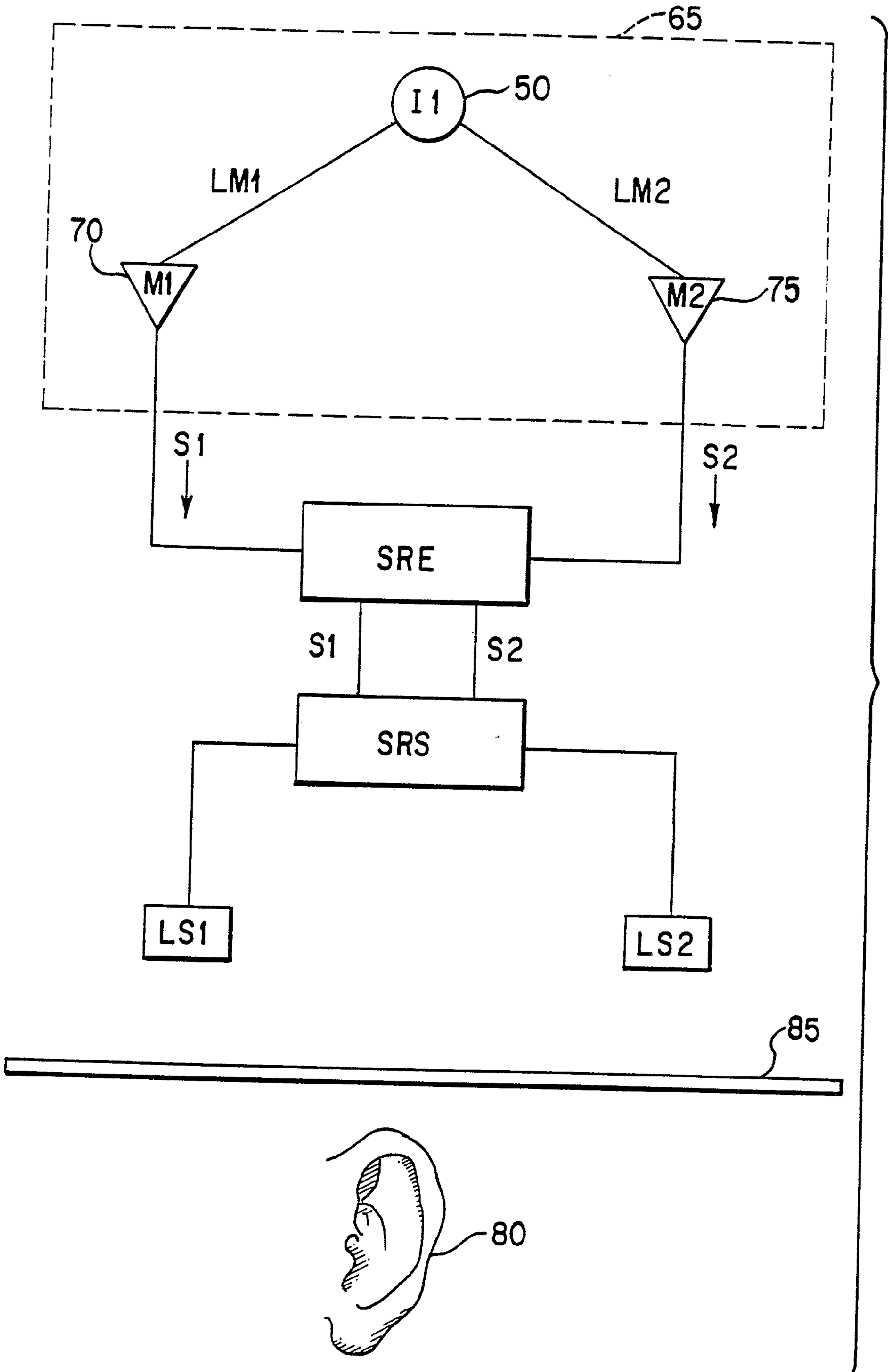

FIG.2

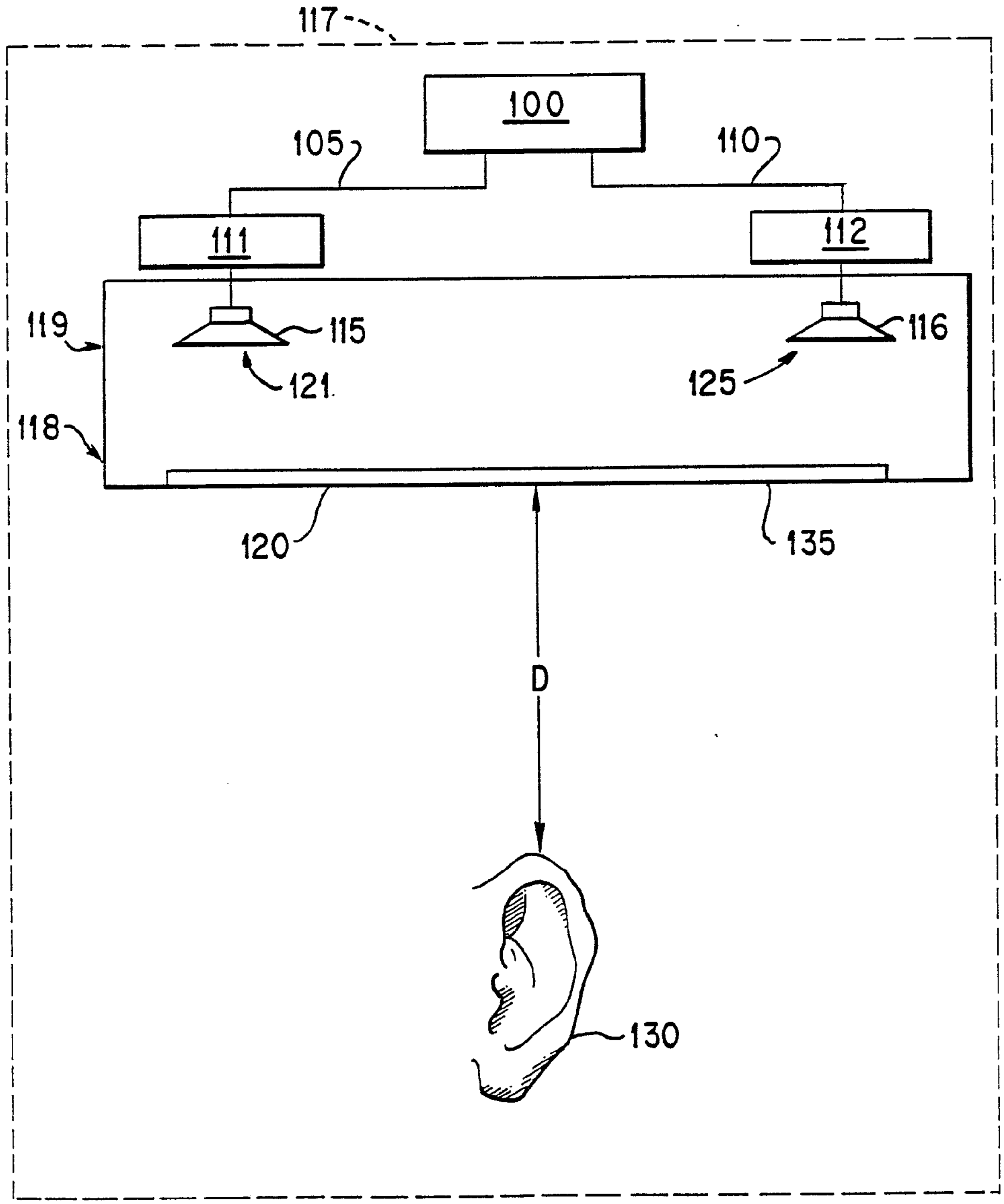

FIG. 3

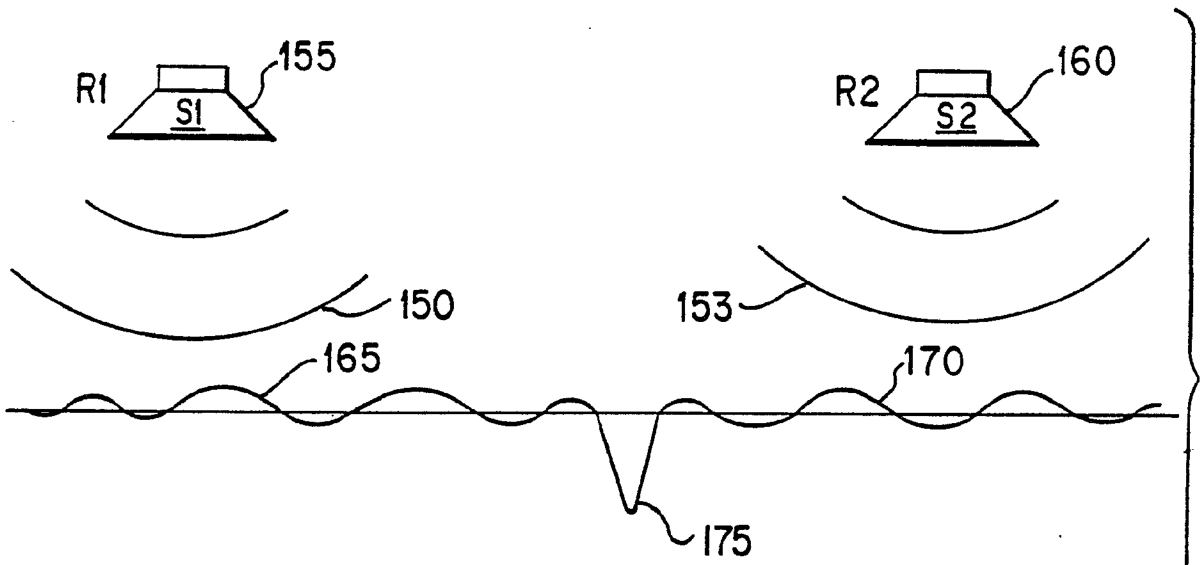

FIG.4

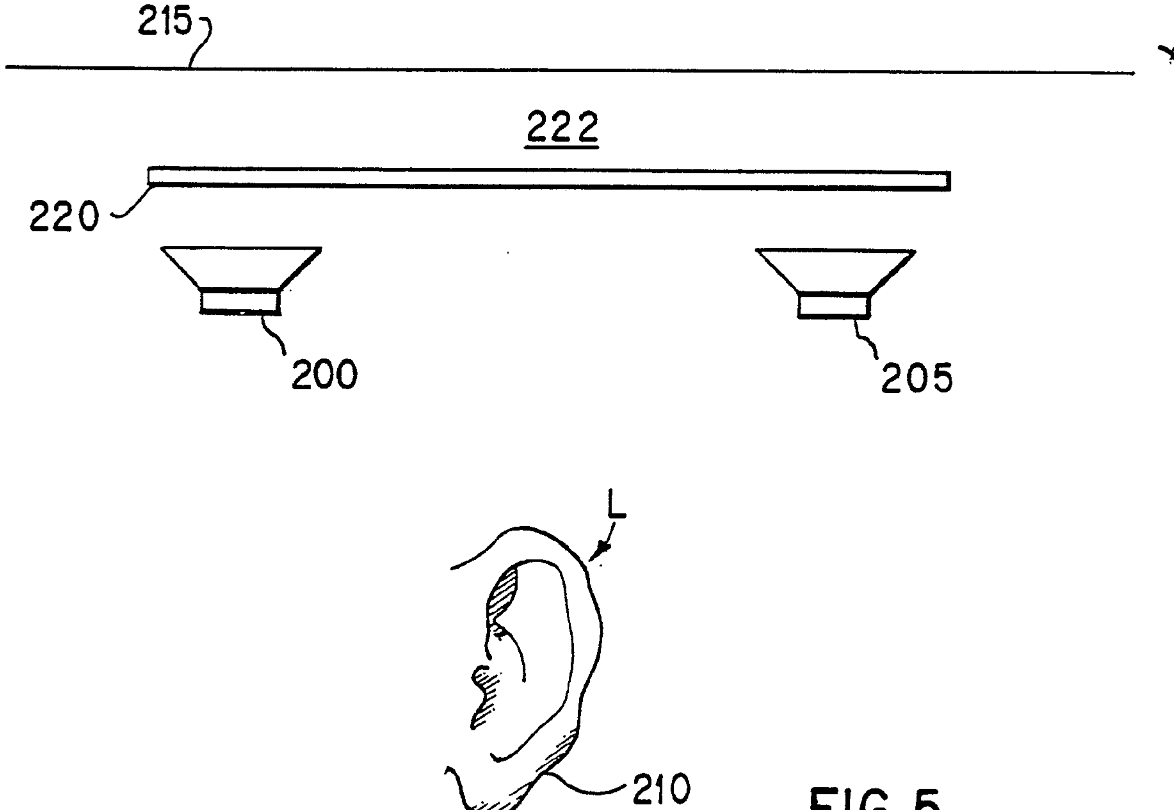

FIG.5

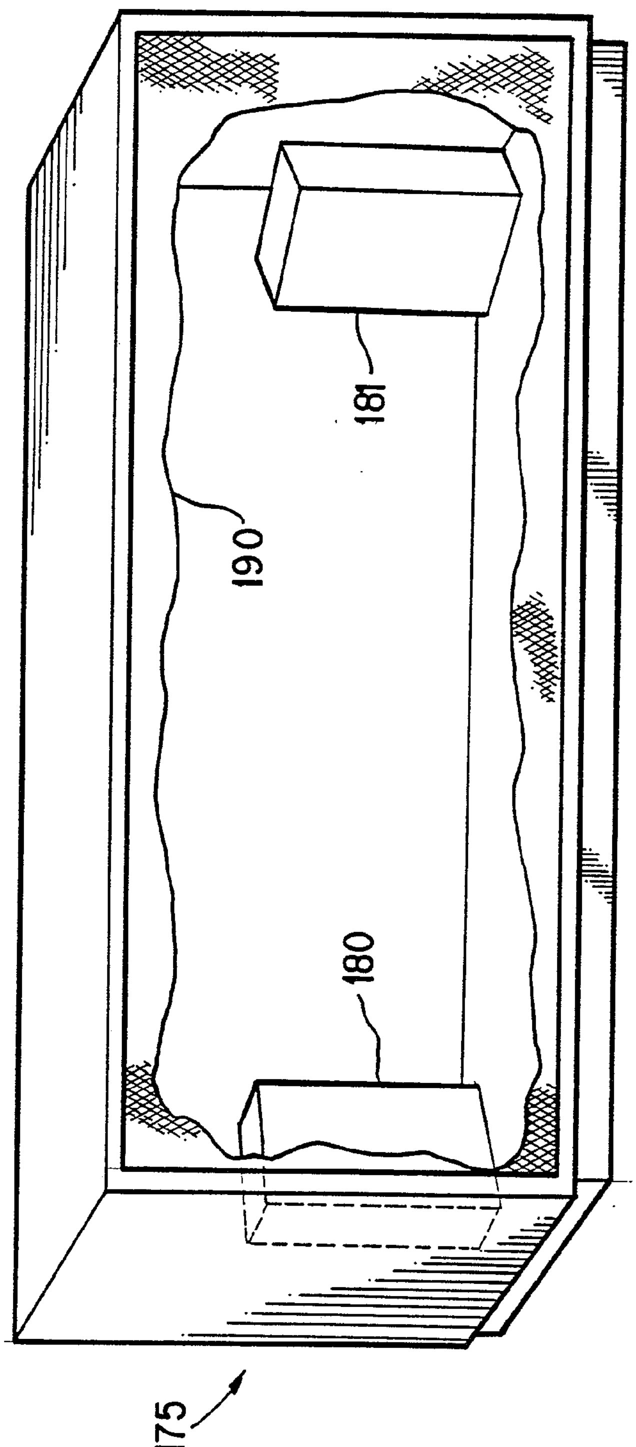

FIG. 6

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/02513

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[4] H04R 5/02

U.S. CL. 381/24

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U.S.	381/24, 205

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4,507,816 (SMITH, JR.) 02 April 1985, See abstract, figure 1, and column 4, lines 21 to 64.	1-6
X	US, A, 4,569,076 (HOLMAN) 04 February 1986, See abstract, figure 1, and column 2, lines 9-22 and lines 48-68.	1-6

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
03 July 1989	04 AUG 1989
International Searching Authority	**Signature of Authorized Officer**
ISA/US	F.W. Isen - Primary Examiner